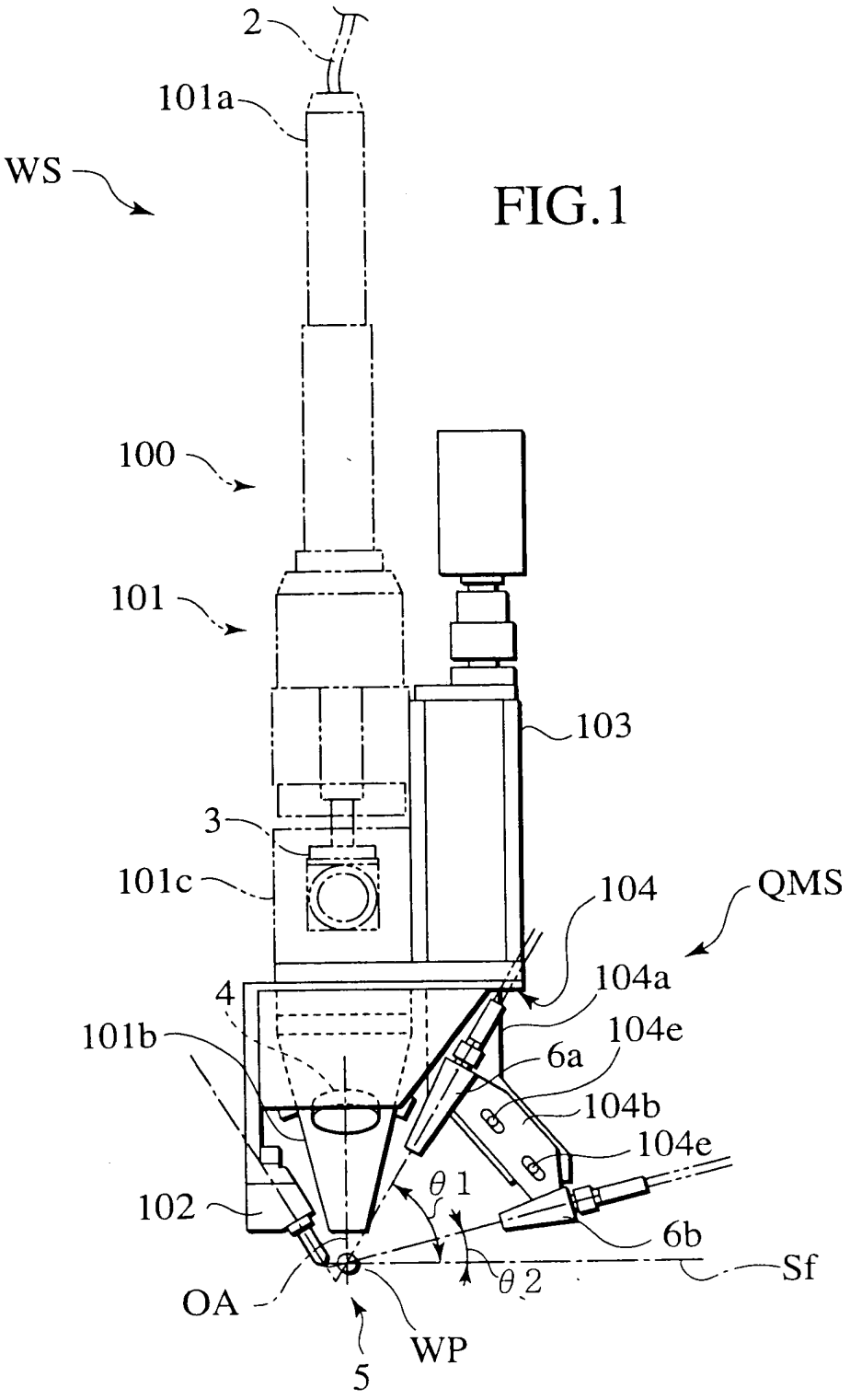

2
101a
WS
100
101
103
3
101c
104
QMS
104a
4
101b
104e
6a
104b
104e
θ1
102
6b
θ2
Sf
OA
WP
5

FIG.1

FIG.2

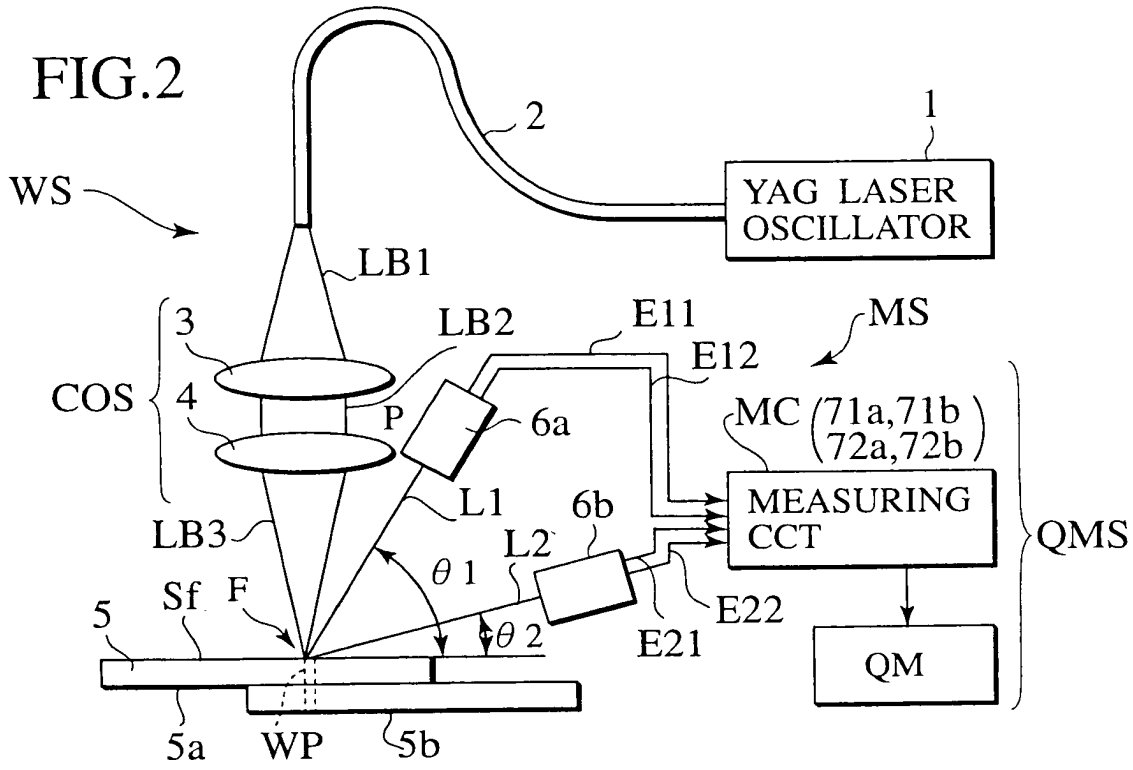

WS
2
1
YAG LASER OSCILLATOR
LB1
3
LB2
E11
MS
E12
COS
4
P
6a
MC (71a,71b 72a,72b)
MEASURING CCT
QMS
L1
6b
LB3
L2
θ1
Sf
F
5
θ2
E22
E21
QM
5a
WP
5b

FIG.3

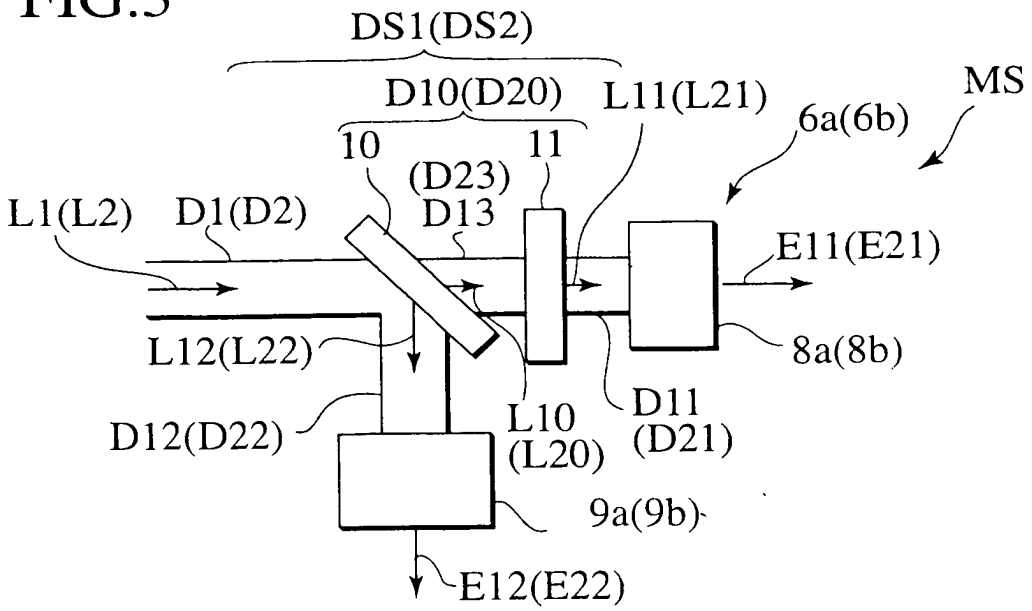

DS1(DS2)
D10(D20)
L11(L21)
MS
6a(6b)
10
11
(D23)
D13
L1(L2)
D1(D2)
E11(E21)
L12(L22)
8a(8b)
D12(D22)
L10
(L20)
D11
(D21)
9a(9b)
E12(E22)

FIG.4

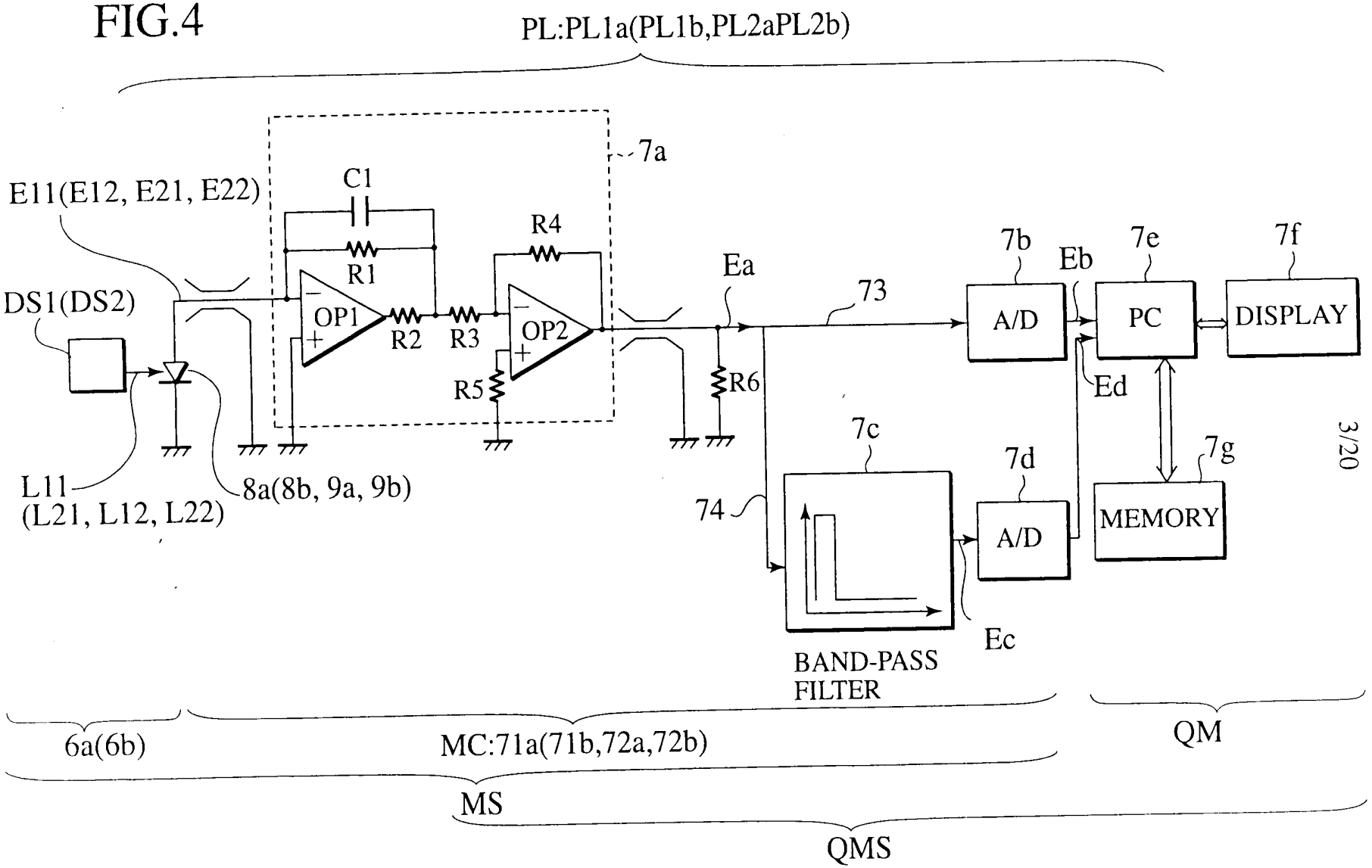

PL:PL1a(PL1b,PL2aPL2b)
7a
C1
R4
E11(E12, E21, E22)
R1
DS1(DS2)
OP1
R2
R3
OP2
R5
R6
Ea
73
7b
Eb
7e
7f
A/D
PC
DISPLAY
Ed
7c
7d
7g
74
A/D
MEMORY
L11
(L21, L12, L22)
8a(8b, 9a, 9b)
BAND-PASS
FILTER
Ec
6a(6b)
MC:71a(71b,72a,72b)
QM
MS
QMS

FIG.5

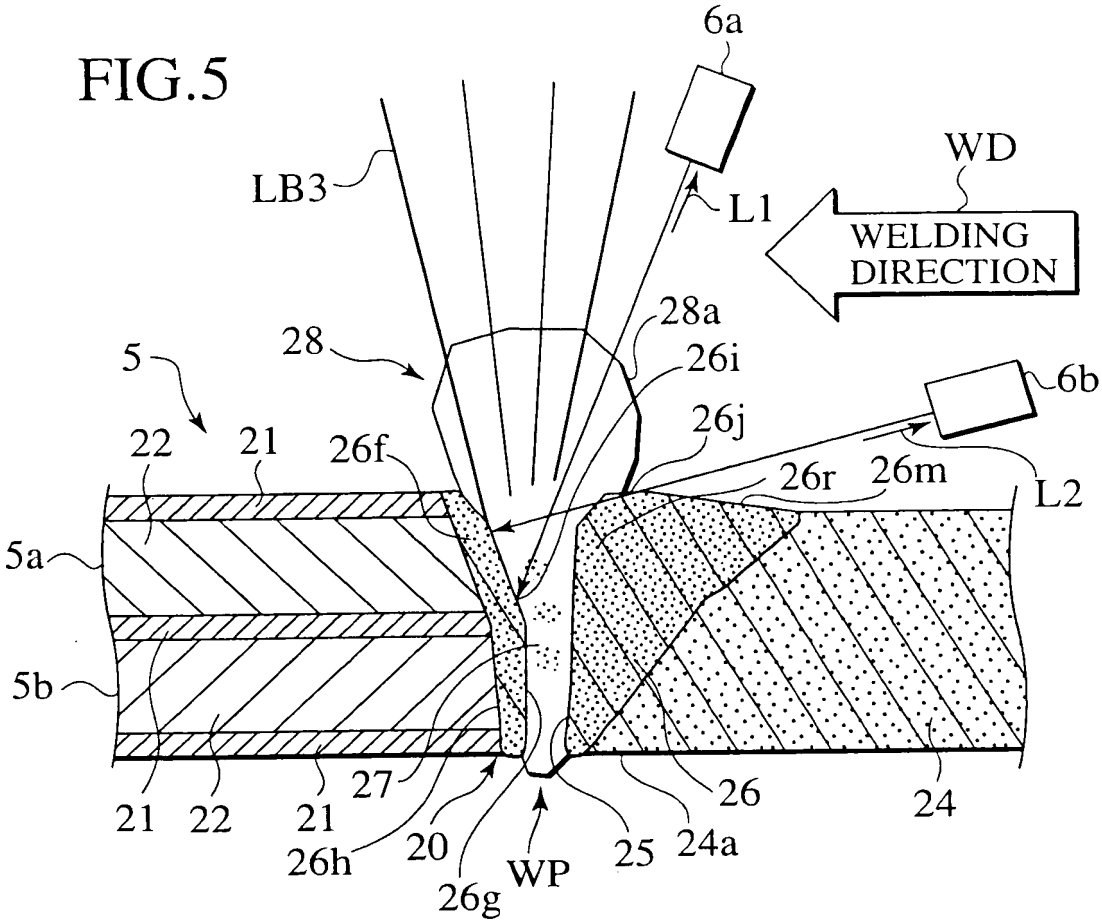

6a
WD
LB3
L1
WELDING
DIRECTION
28a
28
26i
5
6b
26j
22
21
26f
26r
26m
L2
5a
5b
21
22
21
27
26
24
26h
20
WP
25
24a
26g

FIG.6

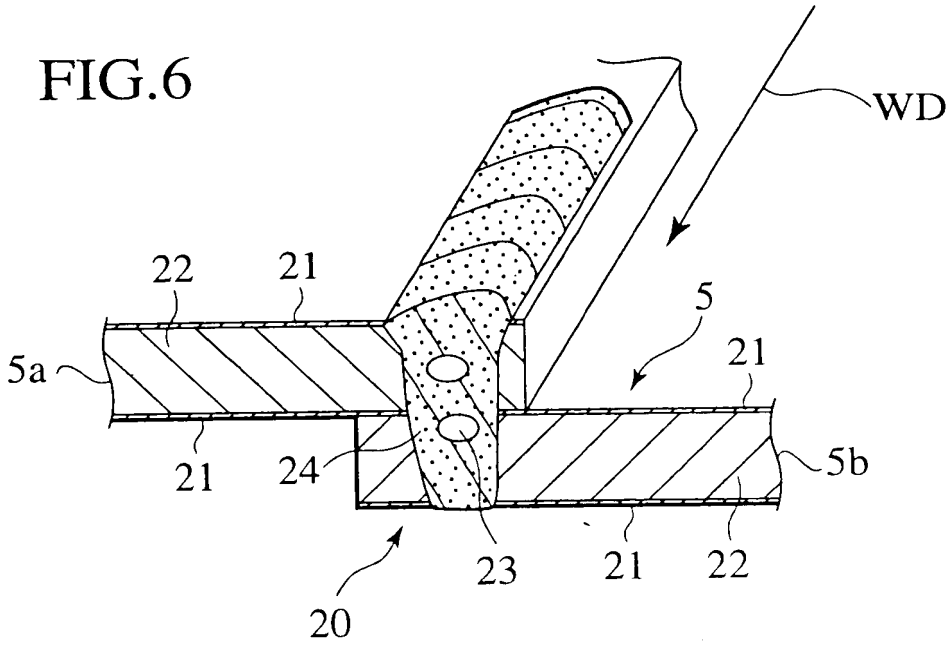

WD
22
21
5
5a
21
21
24
5b
23
21
22
20

FIG.7

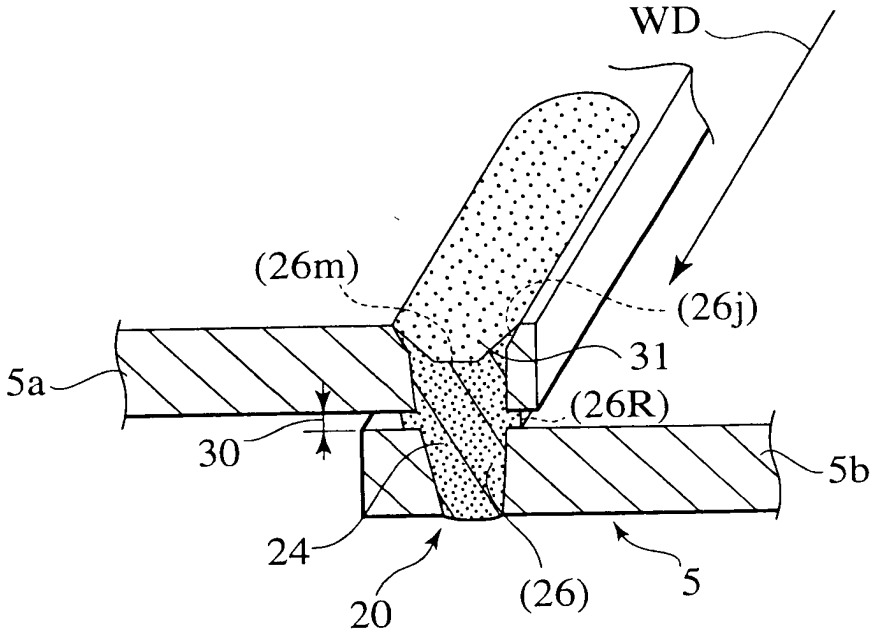


FIG.8

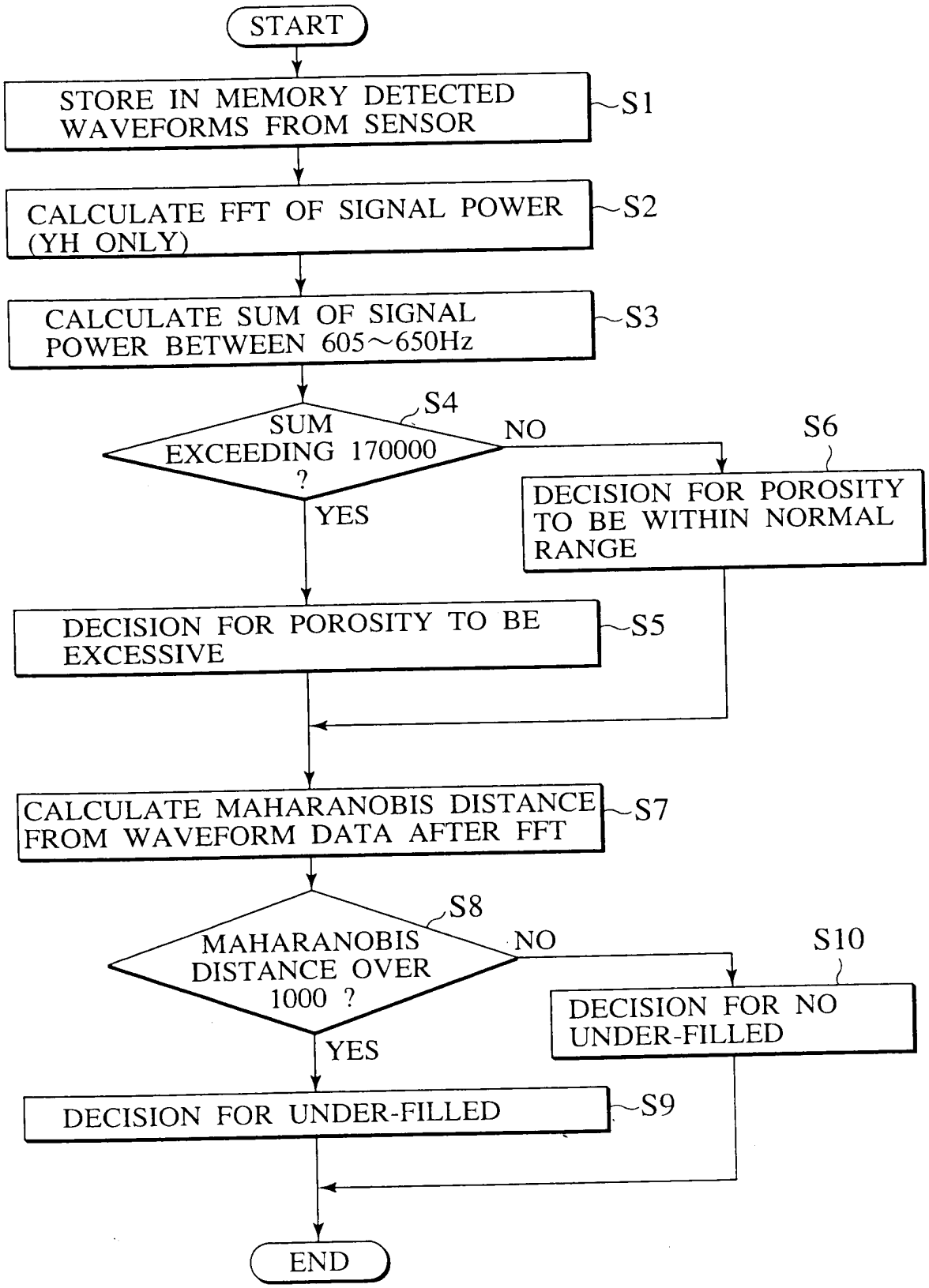
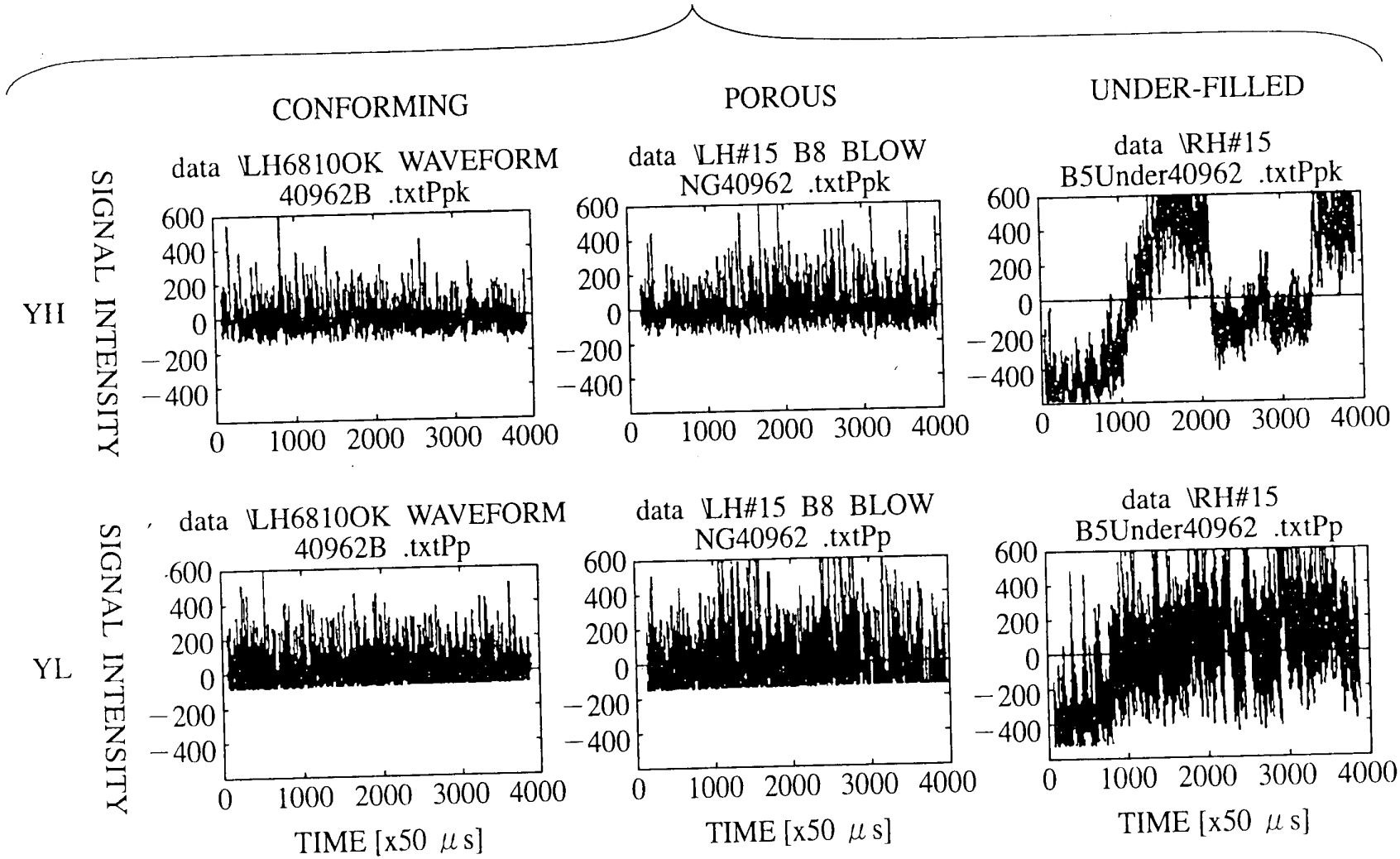

START
STORE IN MEMORY DETECTED WAVEFORMS FROM SENSOR
S1
CALCULATE FFT OF SIGNAL POWER (YH ONLY)
S2
CALCULATE SUM OF SIGNAL POWER BETWEEN 605~650Hz
S3
S4
SUM EXCEEDING 170000 ?
NO
S6
YES
DECISION FOR POROSITY TO BE WITHIN NORMAL RANGE
DECISION FOR POROSITY TO BE EXCESSIVE
S5
CALCULATE MAHARANOBIS DISTANCE FROM WAVEFORM DATA AFTER FFT
S7
S8
MAHARANOBIS DISTANCE OVER 1000 ?
NO
S10
YES
DECISION FOR NO UNDER-FILLED
DECISION FOR UNDER-FILLED
S9
END

FIG.9



DETECTED WAVEFORMS UNDER BASIC WELDING CONDITIONS

FIG.10

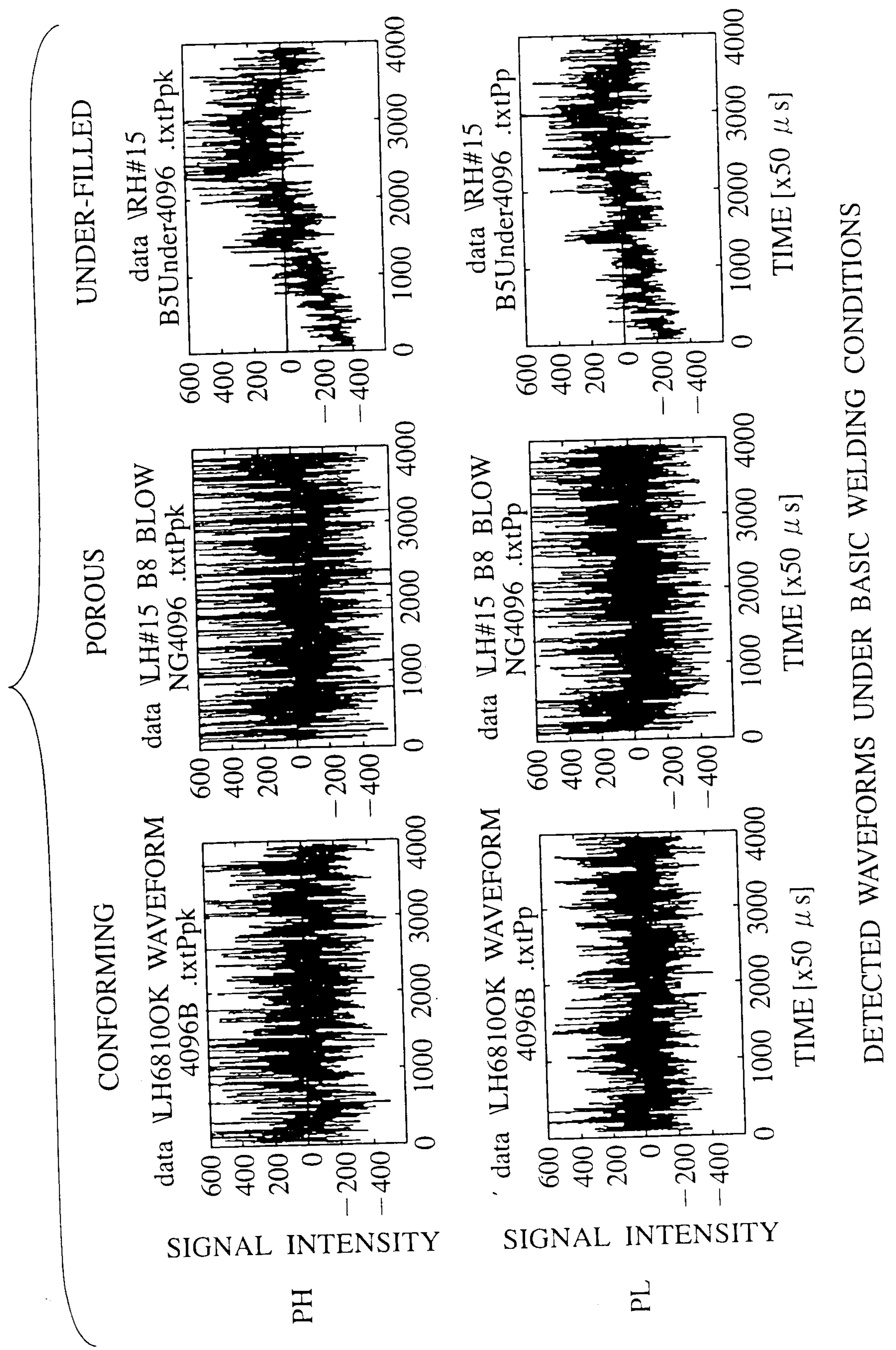

CONFORMING
POROUS
UNDER-FILLED
data \LH6810OK WAVEFORM 4096B .txtPpk
data \LH#15 B8 BLOW NG4096 .txtPpk
data \RH#15 B5Under4096 .txtPpk
data \LH6810OK WAVEFORM 4096B .txtPp
data \LH#15 B8 BLOW NG4096 .txtPp
data \RH#15 B5Under4096 .txtPp
SIGNAL INTENSITY
TIME [x50 μs]
PH
PL
DETECTED WAVEFORMS UNDER BASIC WELDING CONDITIONS

FIG.11

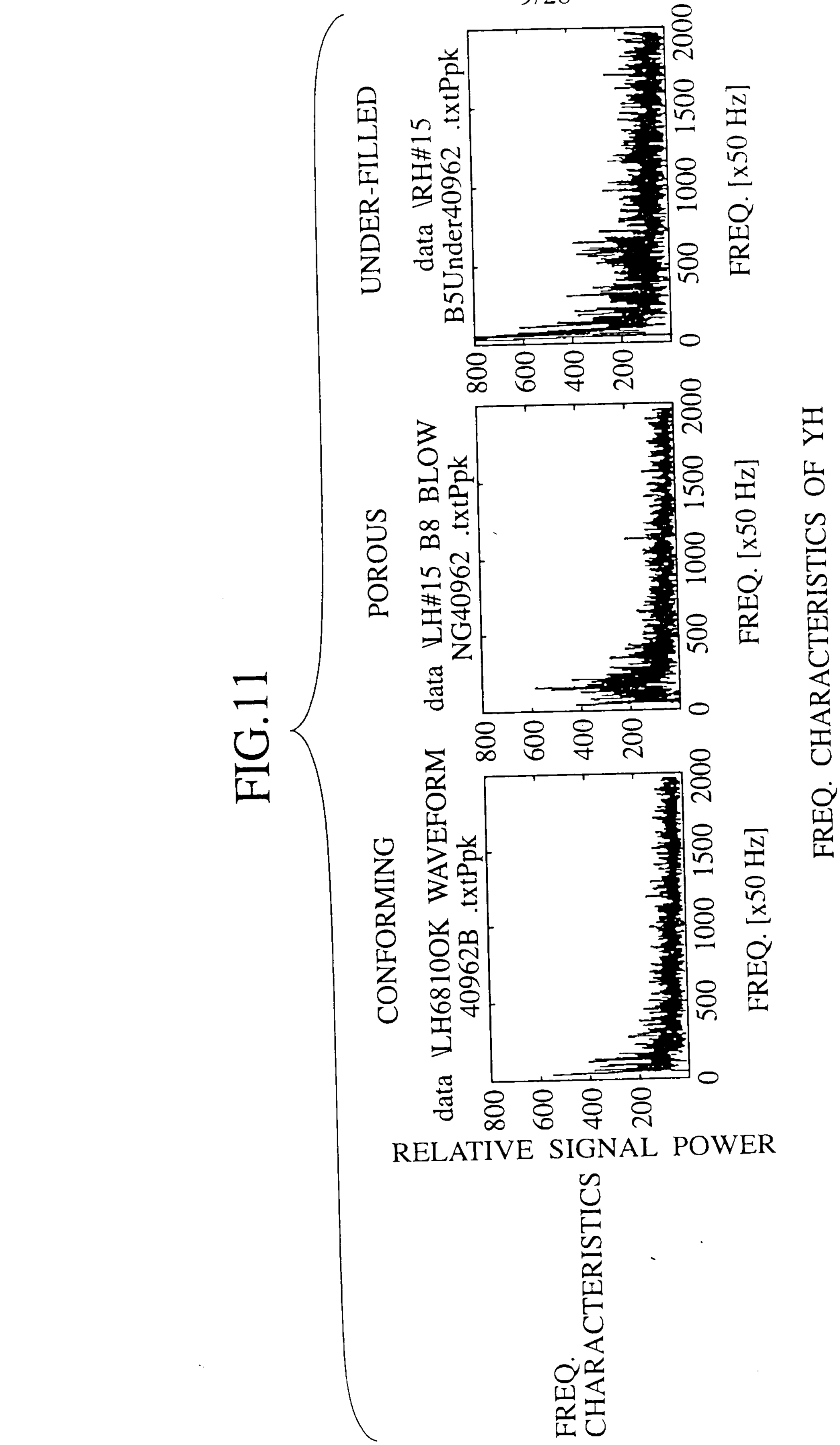

CONFORMING
data \LH6810OK WAVEFORM 40962B .txtPpk
POROUS
data \LH#15 B8 BLOW NG40962 .txtPpk
UNDER-FILLED
data \RH#15 B5Under40962 .txtPpk
800
600
400
200
0
500
1000
1500
2000
FREQ. [x50 Hz]
RELATIVE SIGNAL POWER
FREQ. CHARACTERISTICS
FREQ. CHARACTERISTICS OF YH

FIG.12

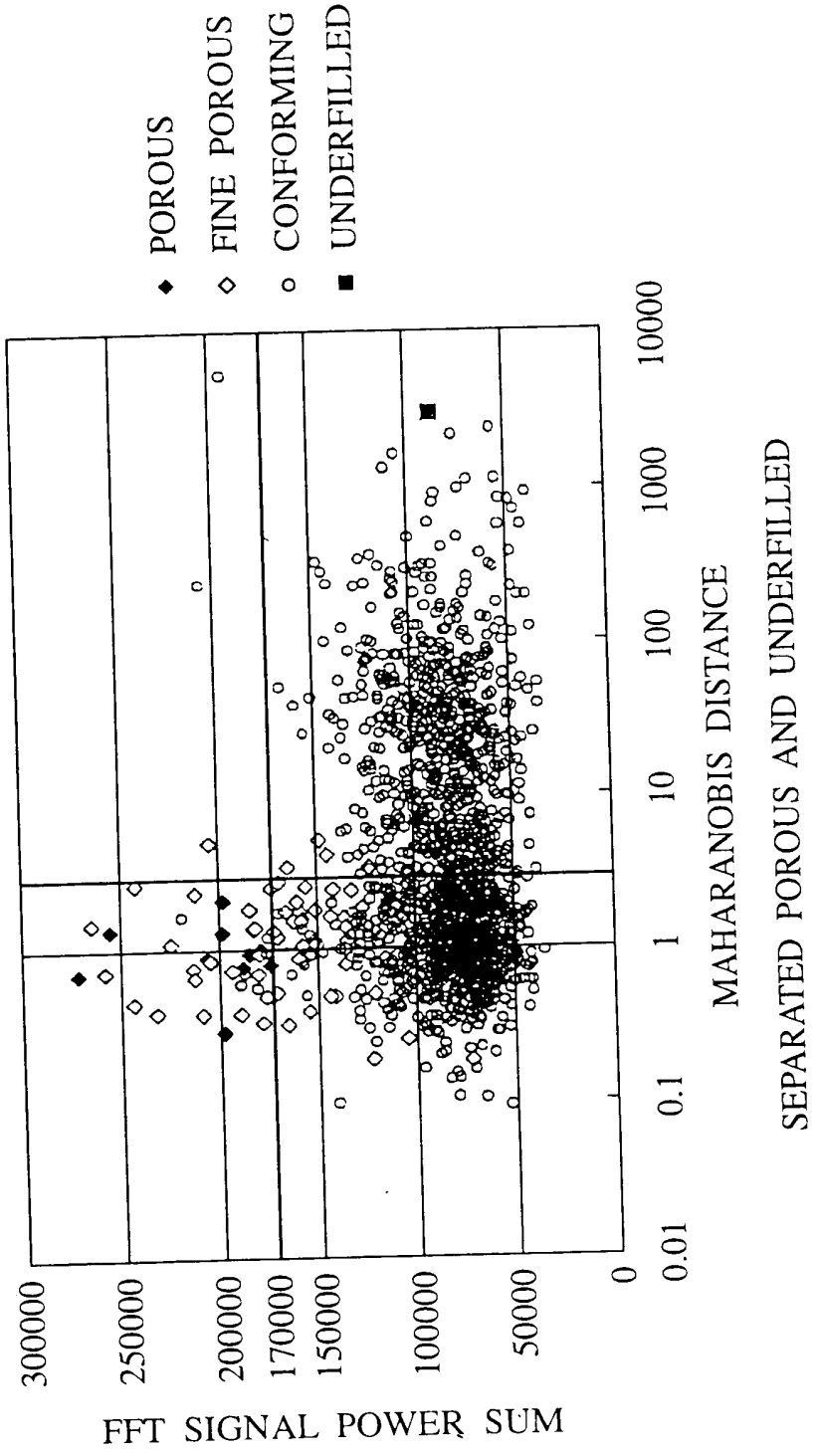

POROUS
FINE POROUS
CONFORMING
UNDERFILLED
300000
250000
200000
170000
150000
100000
50000
0
0.01
0.1
1
10
100
1000
10000
FFT SIGNAL POWER SUM
MAHARANOBIS DISTANCE
SEPARATED POROUS AND UNDERFILLED

FIG.13

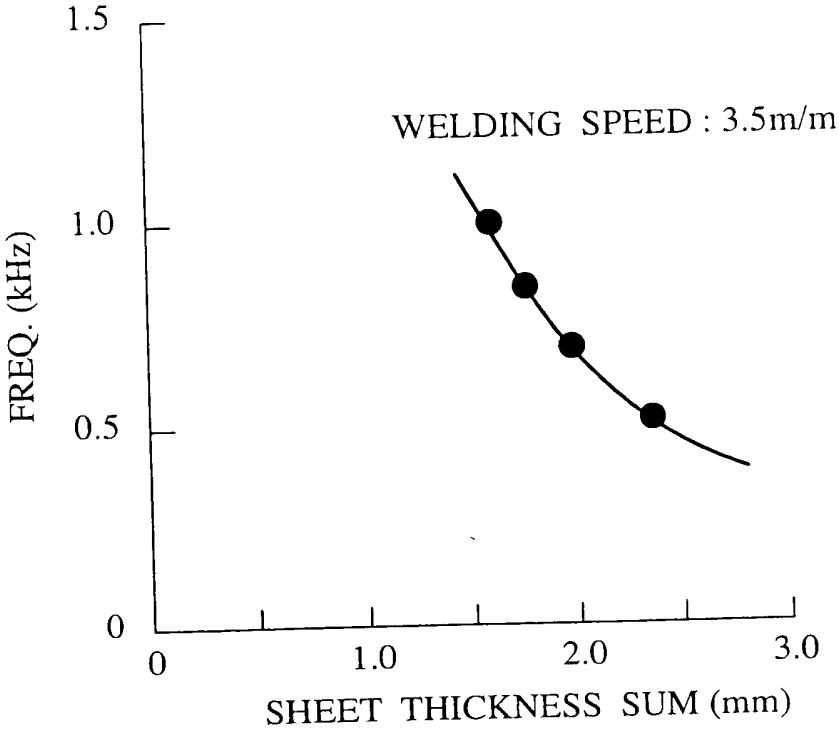

1.5
1.0
0.5
0
FREQ. (kHz)
WELDING SPEED : 3.5m/min.
0
1.0
2.0
3.0
SHEET THICKNESS SUM (mm)

FIG.14

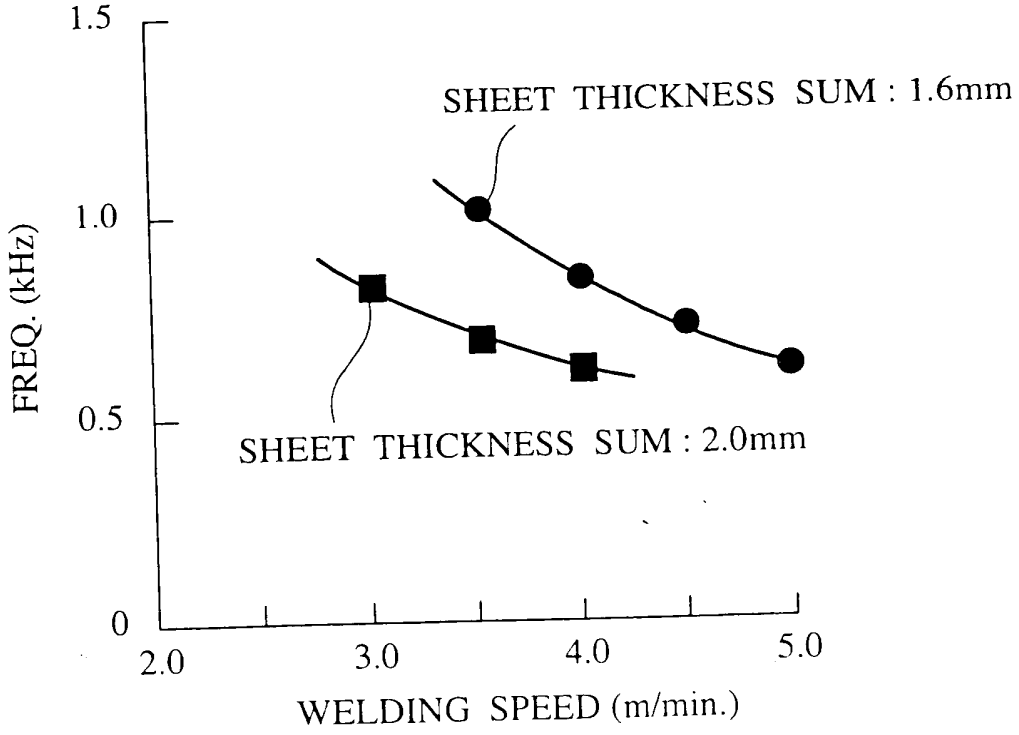

1.5
1.0
0.5
0
FREQ. (kHz)
SHEET THICKNESS SUM : 1.6mm
SHEET THICKNESS SUM : 2.0mm
2.0
3.0
4.0
5.0
WELDING SPEED (m/min.)

FIG.15

TABLE-1

		UPPER SHEET t_1		
	LOWER/UPPER	0.8mm	1.0mm	1.2mm
LOWER SHEET t_2	0.8mm	3.5m/min.	3.5m/min.	3.5m/min.
	〃	4.0m/min.		
	〃	4.5m/min.		
	〃	5.0m/min.		
	1.0mm	3.5m/min.		
	1.2mm	3.0m/min.		
	〃	3.5m/min.		3.5m/min.
	〃	4.0m/min.		

FIG.16

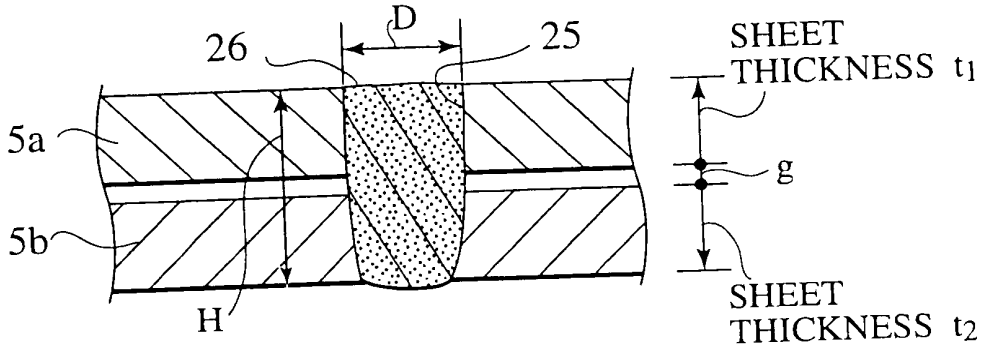

D
26
25
SHEET
THICKNESS t1
5a
g
5b
H
SHEET
THICKNESS t2

FIG.17

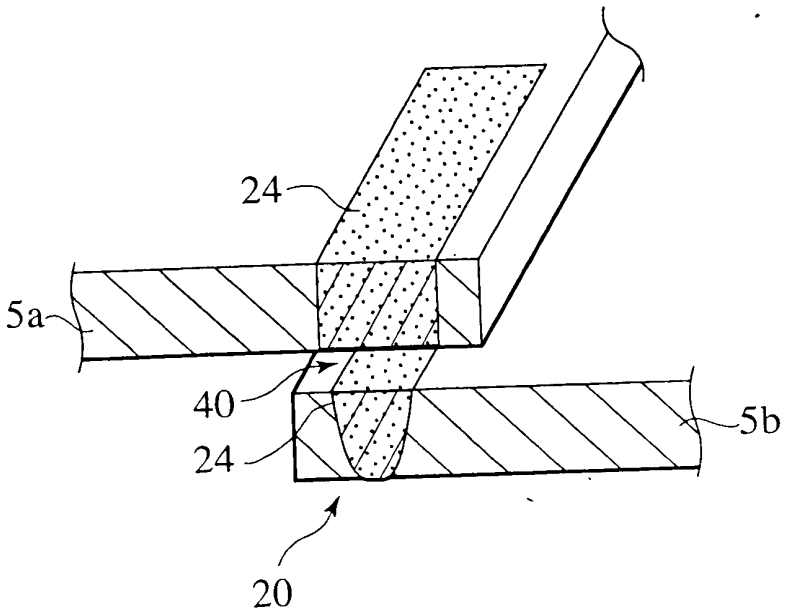

24
5a
40
24
5b
20

FIG.18

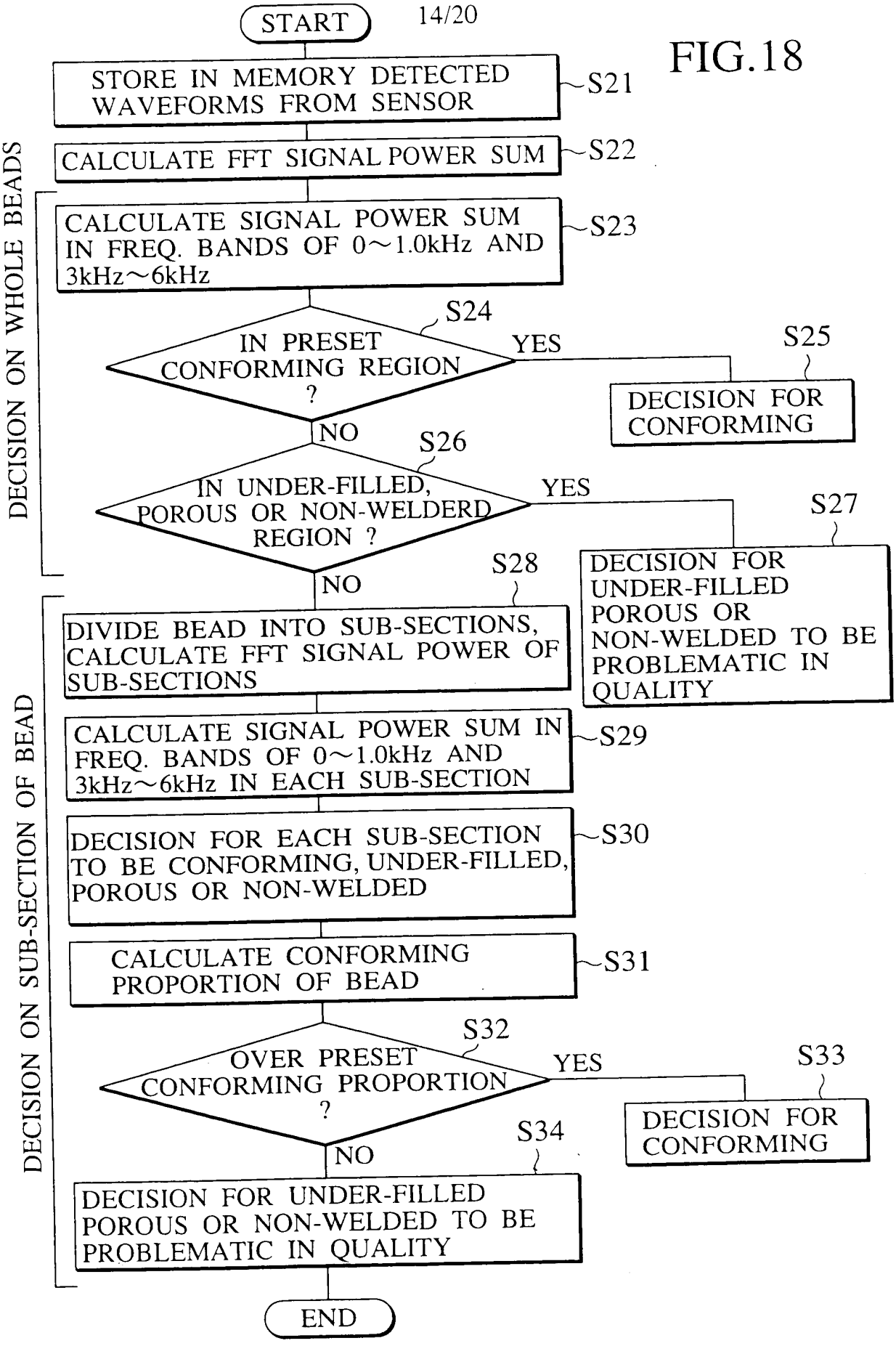

START
STORE IN MEMORY DETECTED WAVEFORMS FROM SENSOR
S21
CALCULATE FFT SIGNAL POWER SUM
S22
CALCULATE SIGNAL POWER SUM IN FREQ. BANDS OF 0~1.0kHz AND 3kHz~6kHz
S23
DECISION ON WHOLE BEADS
S24
IN PRESET CONFORMING REGION ?
YES
S25
DECISION FOR CONFORMING
NO
S26
IN UNDER-FILLED, POROUS OR NON-WELDERD REGION ?
YES
S27
DECISION FOR UNDER-FILLED POROUS OR NON-WELDED TO BE PROBLEMATIC IN QUALITY
NO
S28
DIVIDE BEAD INTO SUB-SECTIONS, CALCULATE FFT SIGNAL POWER OF SUB-SECTIONS
CALCULATE SIGNAL POWER SUM IN FREQ. BANDS OF 0~1.0kHz AND 3kHz~6kHz IN EACH SUB-SECTION
S29
DECISION FOR EACH SUB-SECTION TO BE CONFORMING, UNDER-FILLED, POROUS OR NON-WELDED
S30
CALCULATE CONFORMING PROPORTION OF BEAD
S31
DECISION ON SUB-SECTION OF BEAD
S32
OVER PRESET CONFORMING PROPORTION ?
YES
S33
DECISION FOR CONFORMING
NO
S34
DECISION FOR UNDER-FILLED POROUS OR NON-WELDED TO BE PROBLEMATIC IN QUALITY
END

FIG.19

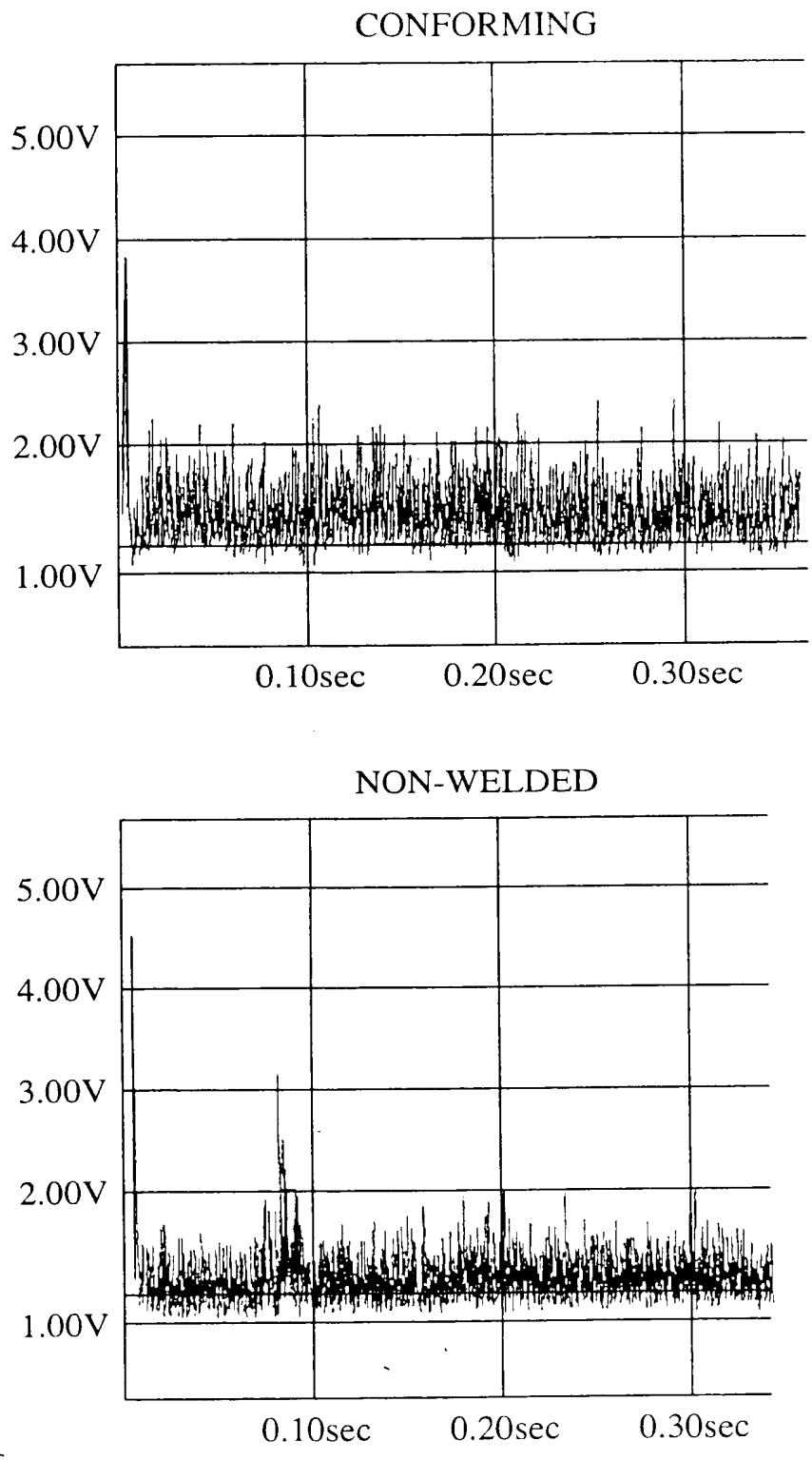

CONFORMING
5.00V
4.00V
3.00V
2.00V
1.00V
0.10sec
0.20sec
0.30sec
NON-WELDED
5.00V
4.00V
3.00V
2.00V
1.00V
0.10sec
0.20sec
0.30sec

FIG.20

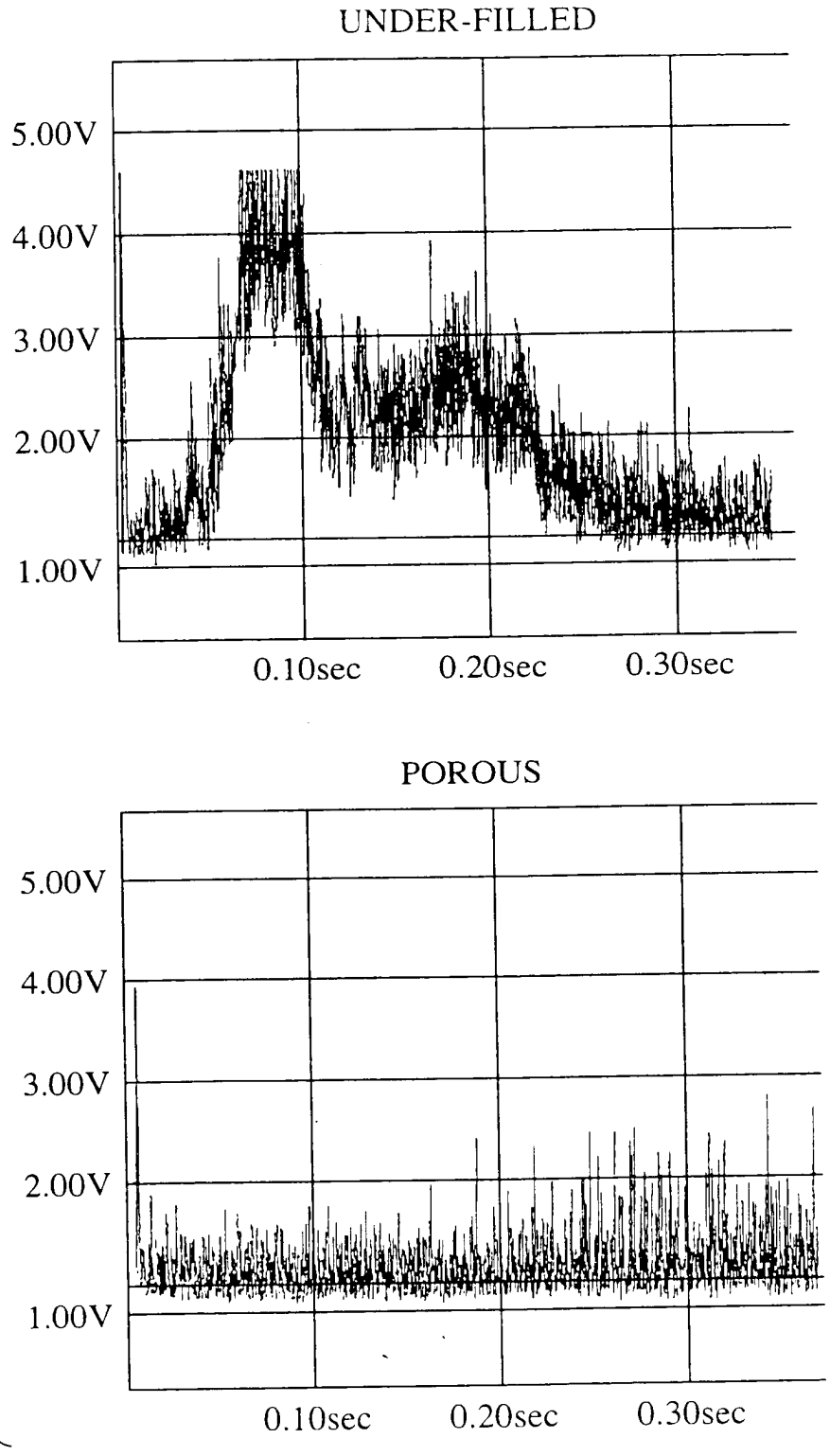

UNDER-FILLED
5.00V
4.00V
3.00V
2.00V
1.00V
0.10sec
0.20sec
0.30sec
POROUS
5.00V
4.00V
3.00V
2.00V
1.00V
0.10sec
0.20sec
0.30sec

FIG.21

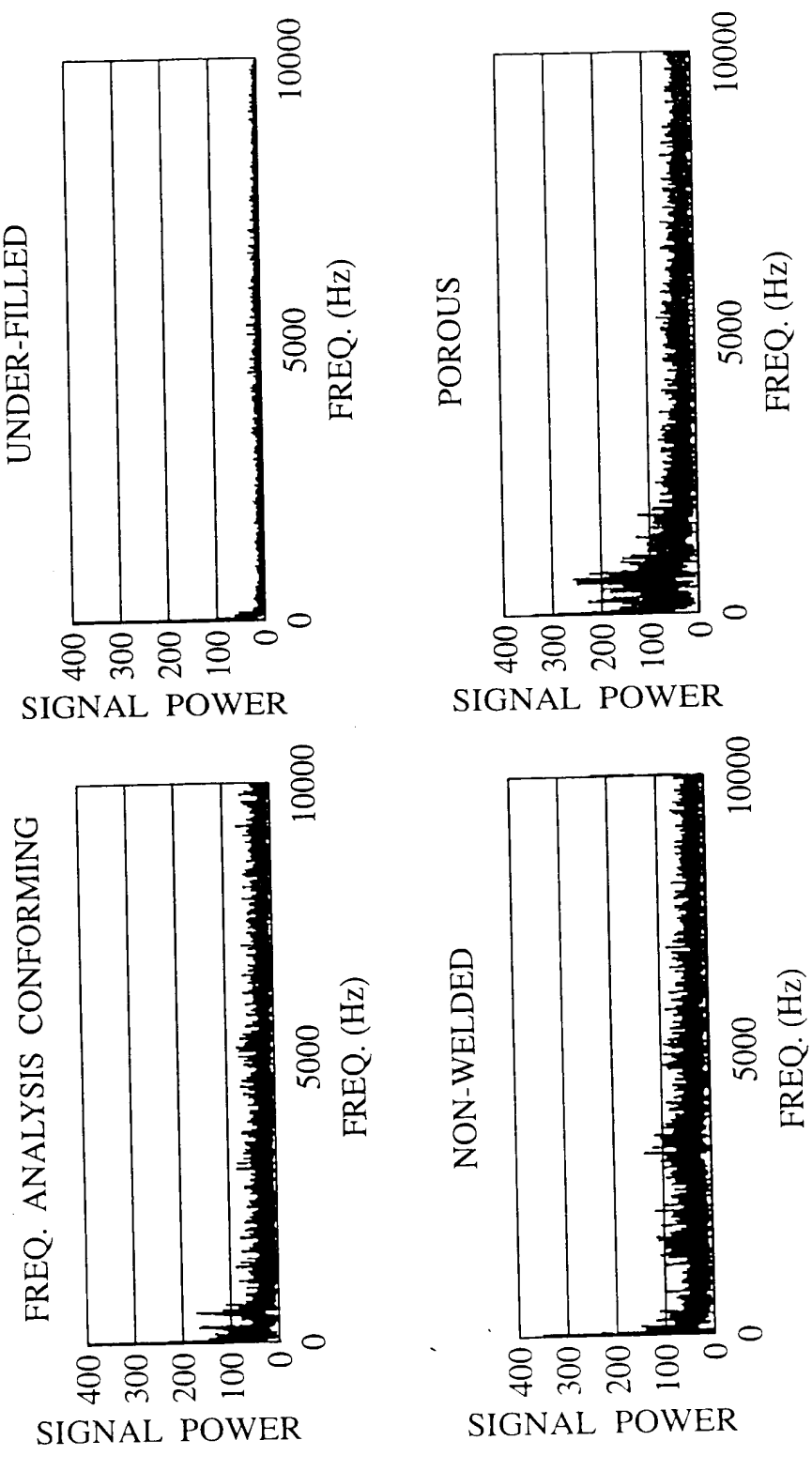

UNDER-FILLED
POROUS
FREQ. ANALYSIS CONFORMING
NON-WELDED
SIGNAL POWER
FREQ. (Hz)
0
100
200
300
400
5000
10000

FIG.22

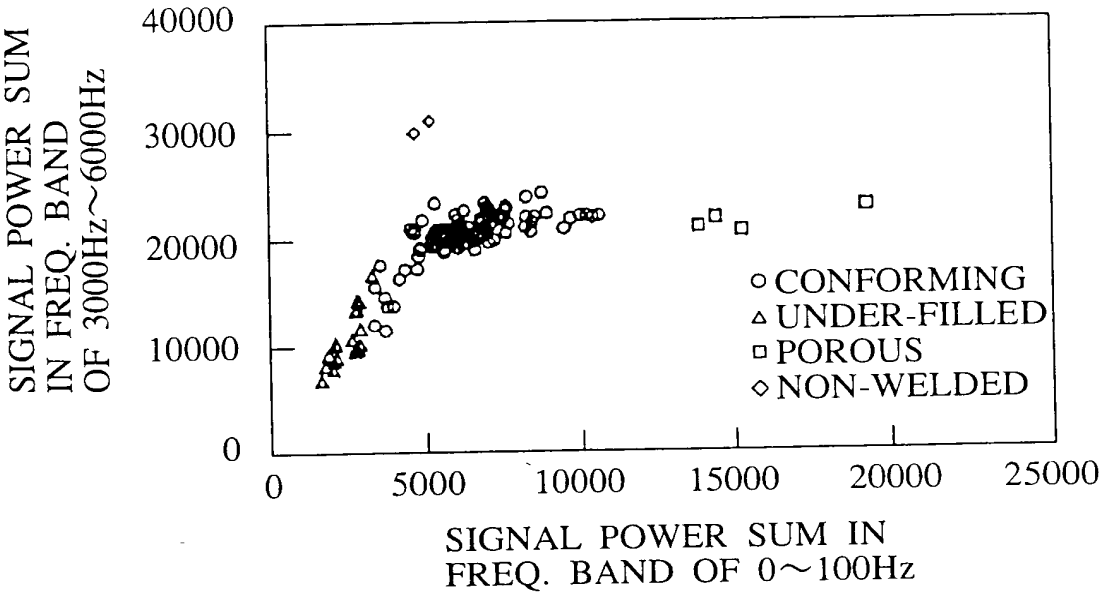

SIGNAL POWER SUM IN FREQ. BAND OF 3000Hz~6000Hz
40000
30000
20000
10000
0
0
5000
10000
15000
20000
25000
SIGNAL POWER SUM IN FREQ. BAND OF 0~100Hz
CONFORMING
UNDER-FILLED
POROUS
NON-WELDED

FIG.23

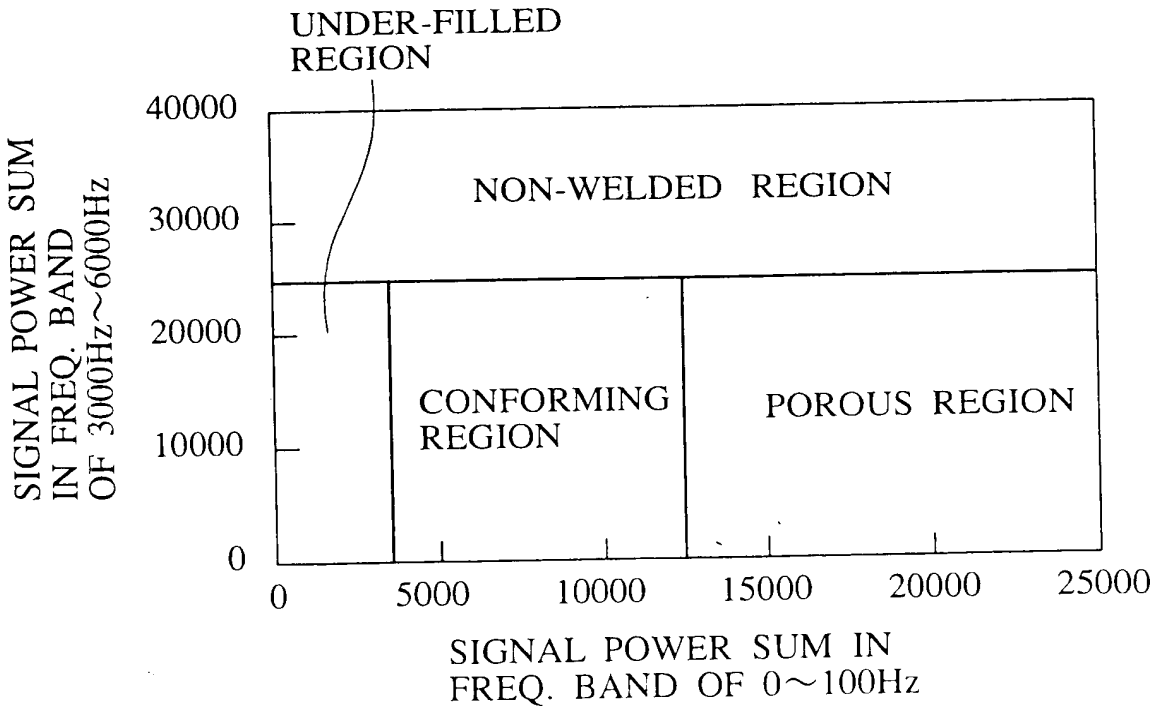

UNDER-FILLED REGION
NON-WELDED REGION
CONFORMING REGION
POROUS REGION
SIGNAL POWER SUM IN FREQ. BAND OF 3000Hz~6000Hz
40000
30000
20000
10000
0
0
5000
10000
15000
20000
25000
SIGNAL POWER SUM IN FREQ. BAND OF 0~100Hz

FIG.24

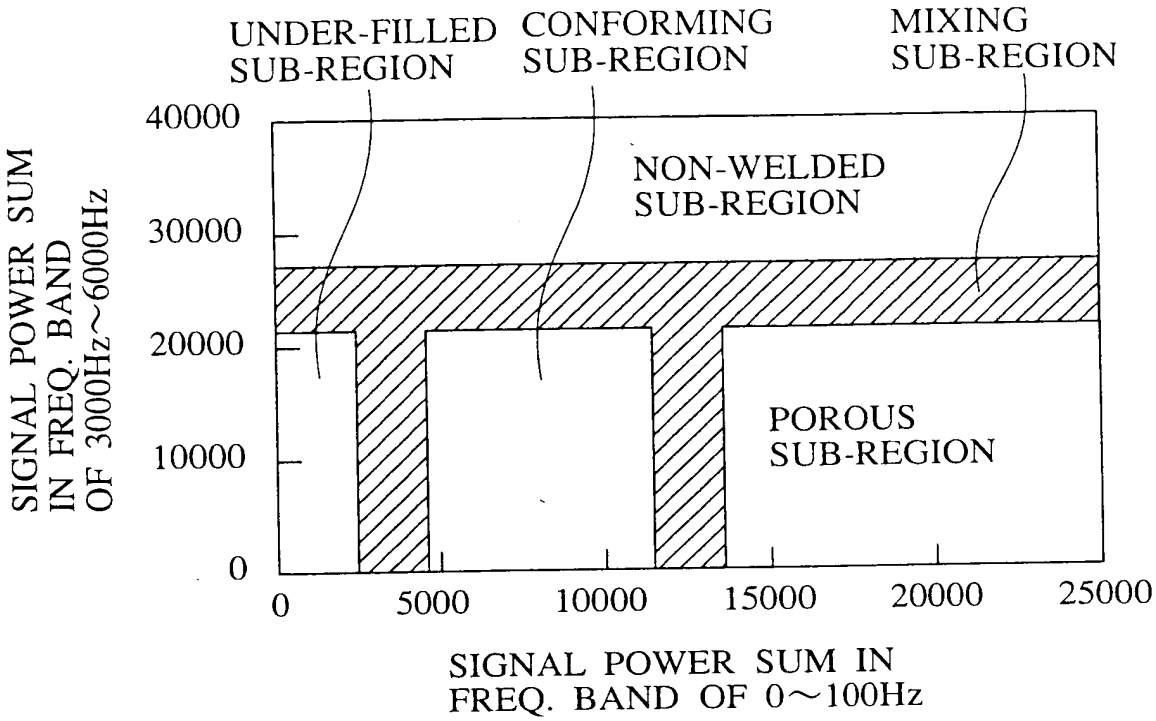
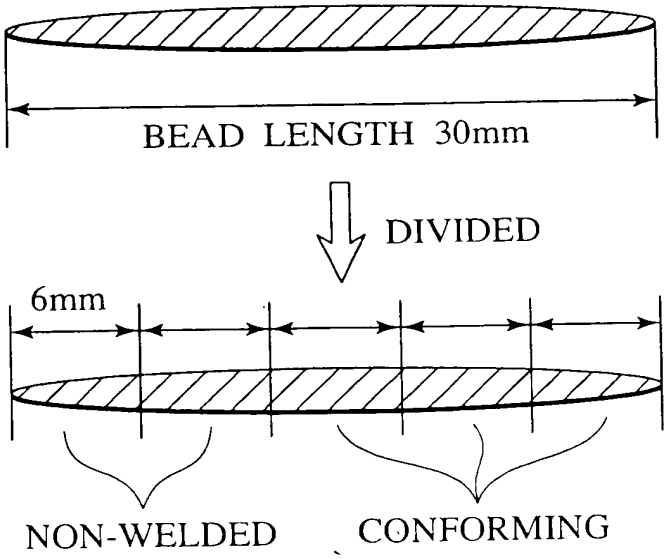


FIG.25



$$\text{CONFORMING PROPORTION} = \frac{\text{CONFORMING LENGTH 6mm} \times 3 \text{ SUB-SECTIONS}}{\text{TOTAL WELD LENGTH 30mm}} = 0.6$$

FIG.26